

Drilling and Blasting Issues and Recommended Mitigation Measures for Residences at South Brookline (Hancock Village)

by

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Summary of Qualifications

Andrew McKown, P.E.

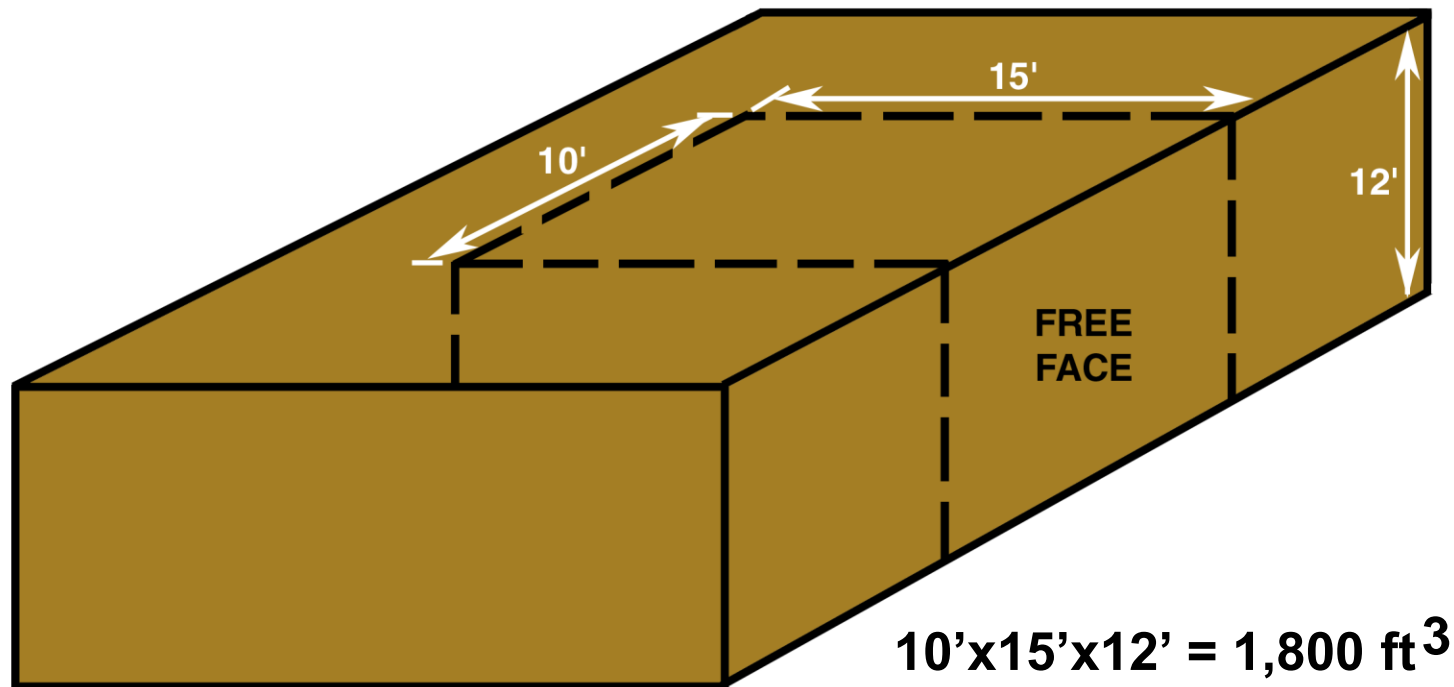
- **B.S. Civil Engineering, Tufts University**
- **M.S. Civil Engineering, MIT**
- **Professional Engineering License, MA**
- **Authored over 20 Professional papers on Blasting and Rock Engineering**
- **Over 35 Years Consulting on Drilling and Blasting and Rock Engineering projects.**

OUTLINE OF PRESENTATION

- **Principals of Multiple Hole Delay Blasting (Blasting Primer)**
- **Impacts of Blasting**
- **Important Issues and Solutions**
- **Summary and Recommendations**

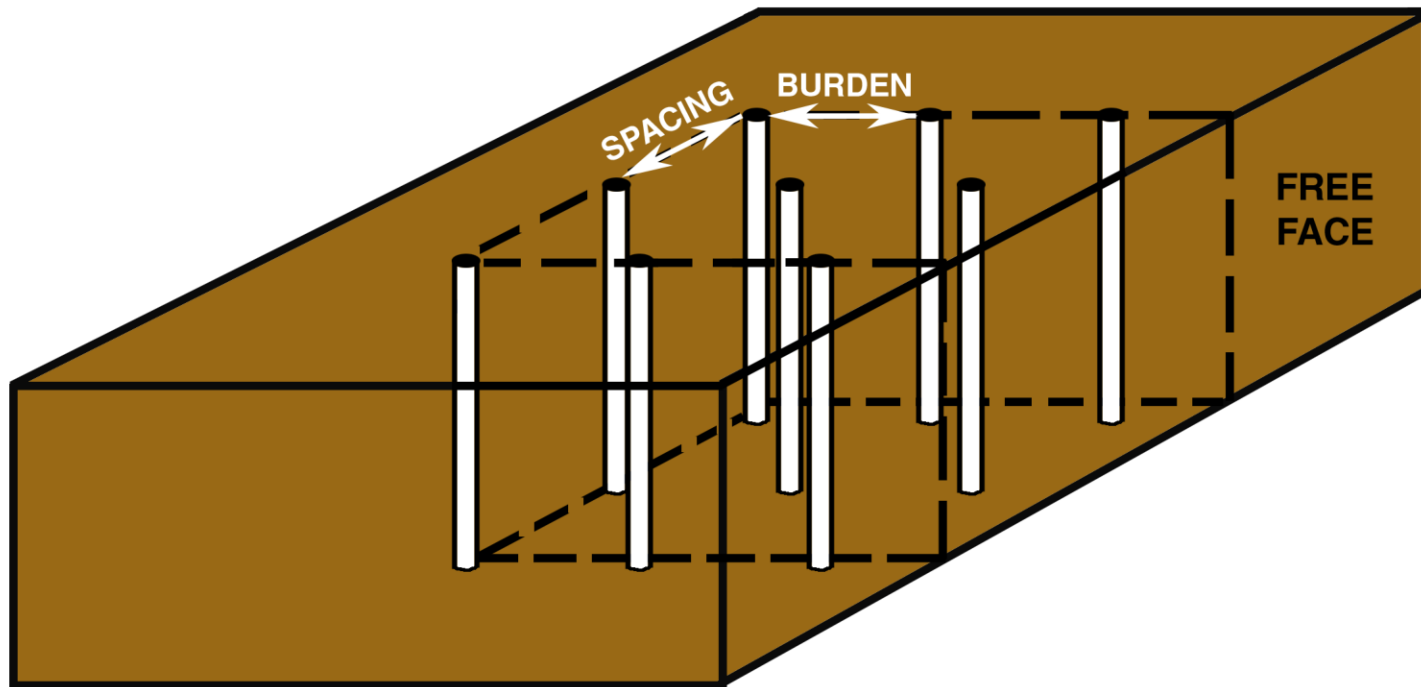
Blasting Primer

Three Dimensional View of Rock to be Removed - Bench Blasting

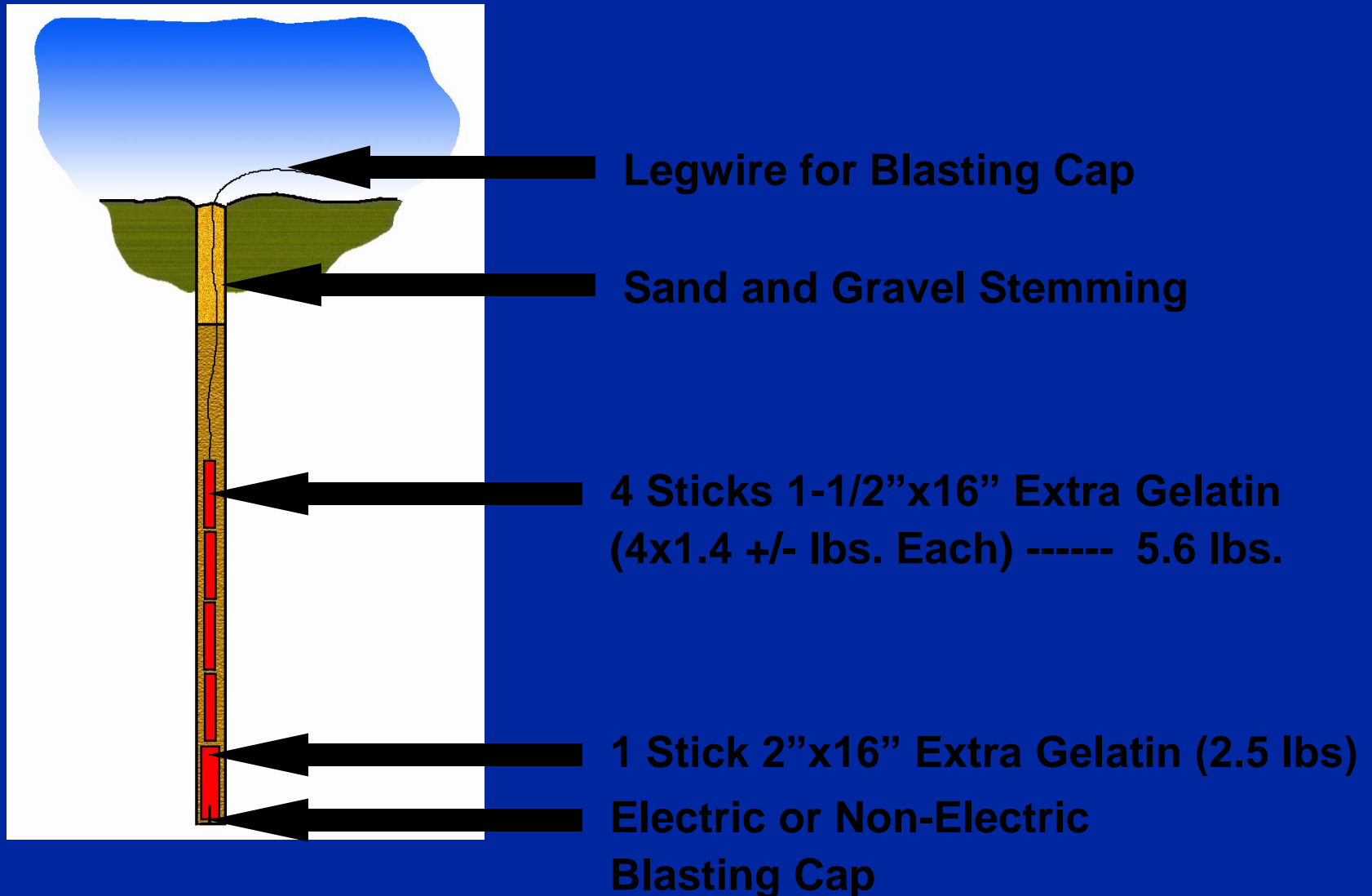


$$\begin{aligned} 10' \times 15' \times 12' &= 1,800 \text{ ft}^3 \\ &= 67 \text{ yd}^3 \end{aligned}$$

Three Dimensional View of Drill Holes for - Bench Blasting

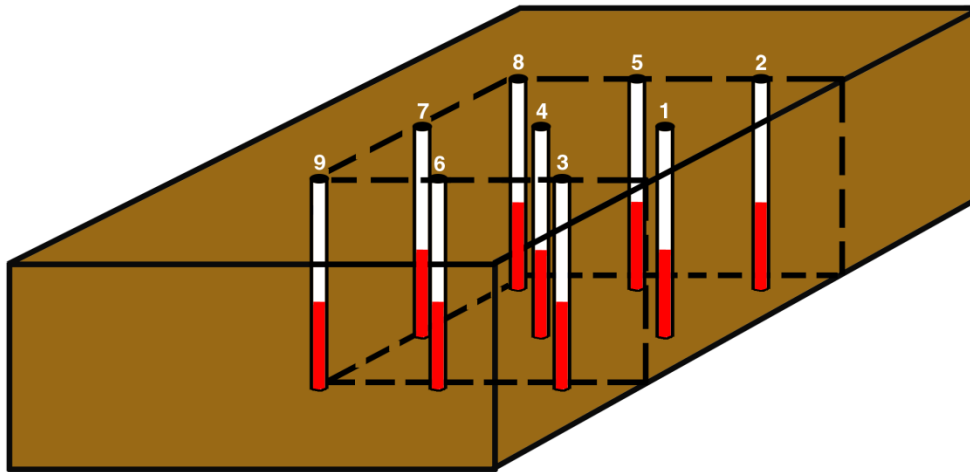


Typical Hole Loading



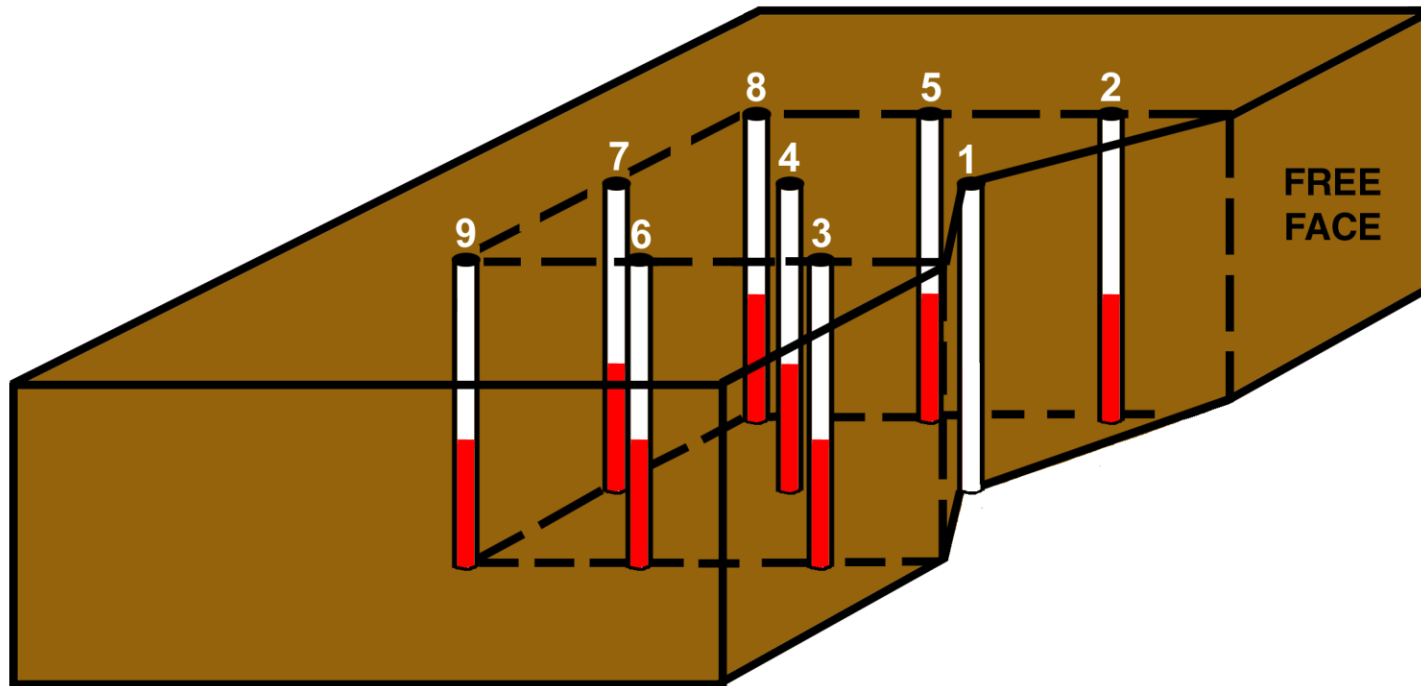
Typical Bench Blast Round Design

- 8.1 lbs. Per hole x 9 holes = 72.9 lbs.
- Powder Factor = $72.9\text{lbs} / 67\text{cy} = 1.08\text{lbs/cy}$
- Each hole on separate delay (1 thru 9)

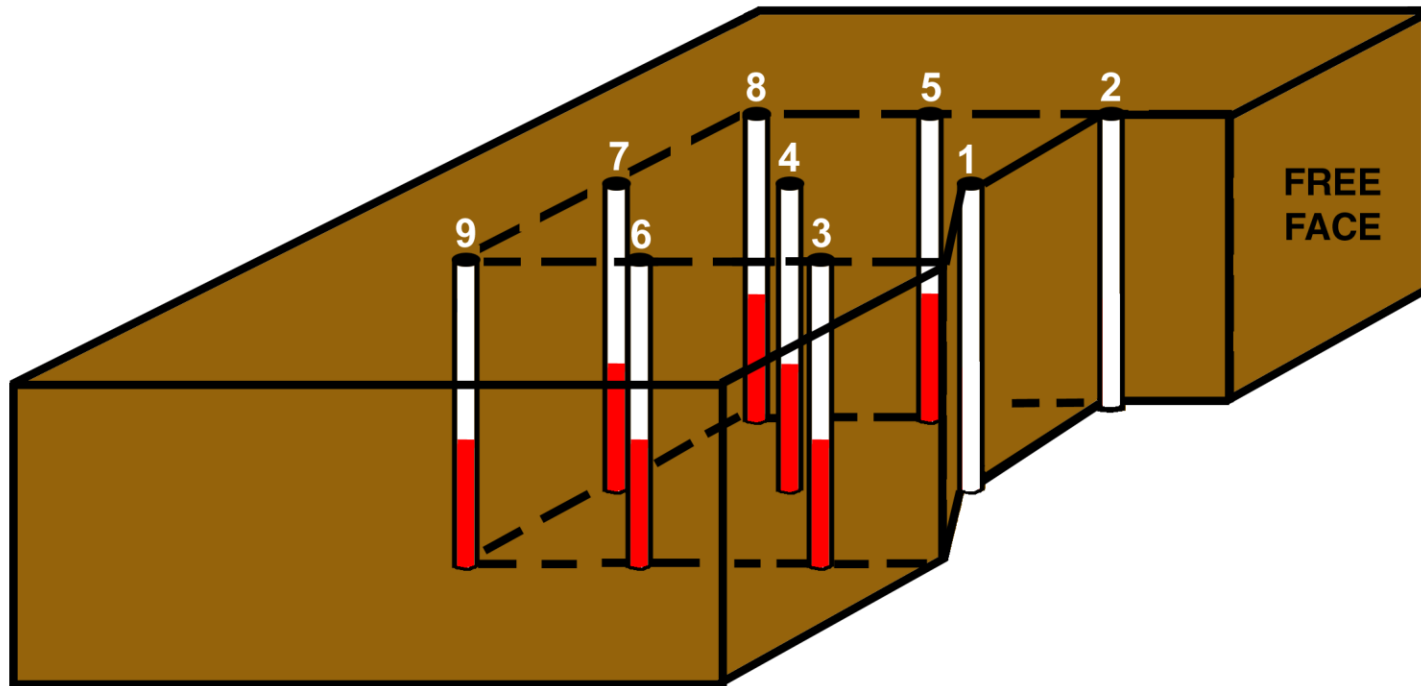


Delay Number	Average Firing Time (milliseconds)
1	25
2	50
3	75
4	100
5	125
6	150
7	175
8	200
9	225

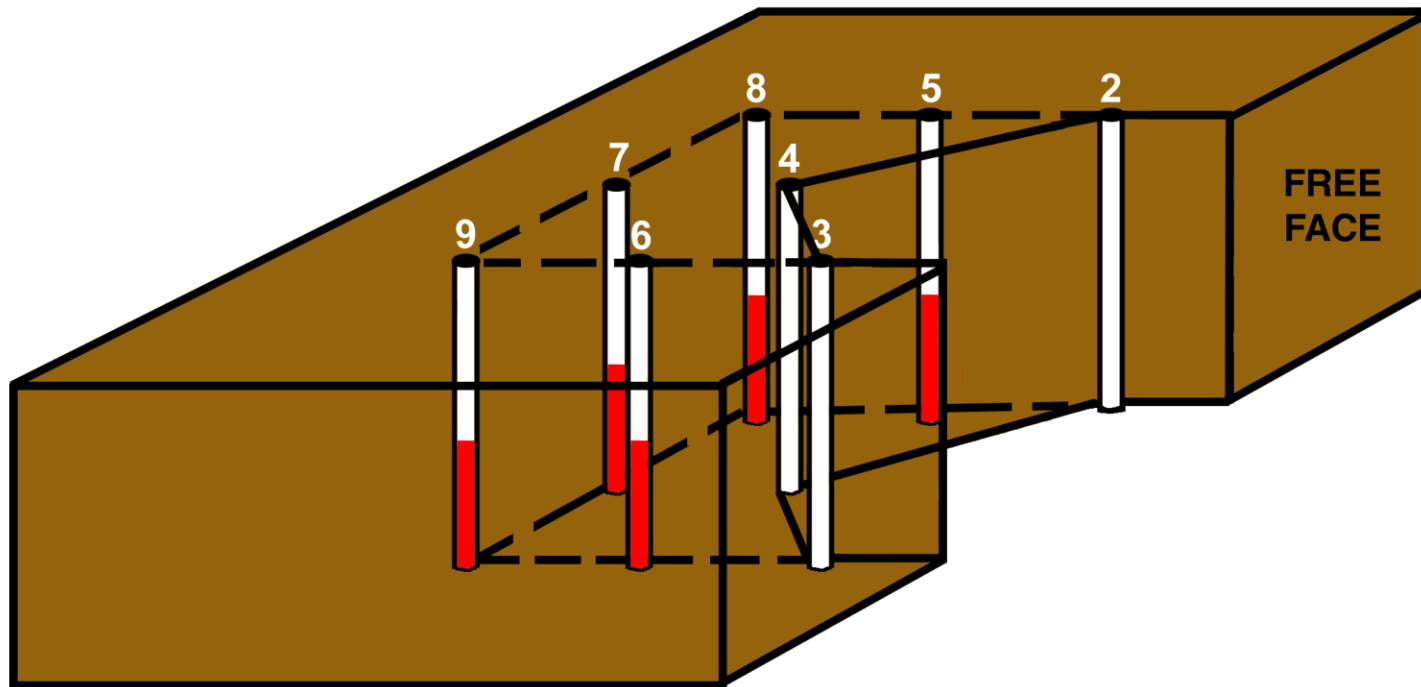
Bench Blast Round - After Delay 1



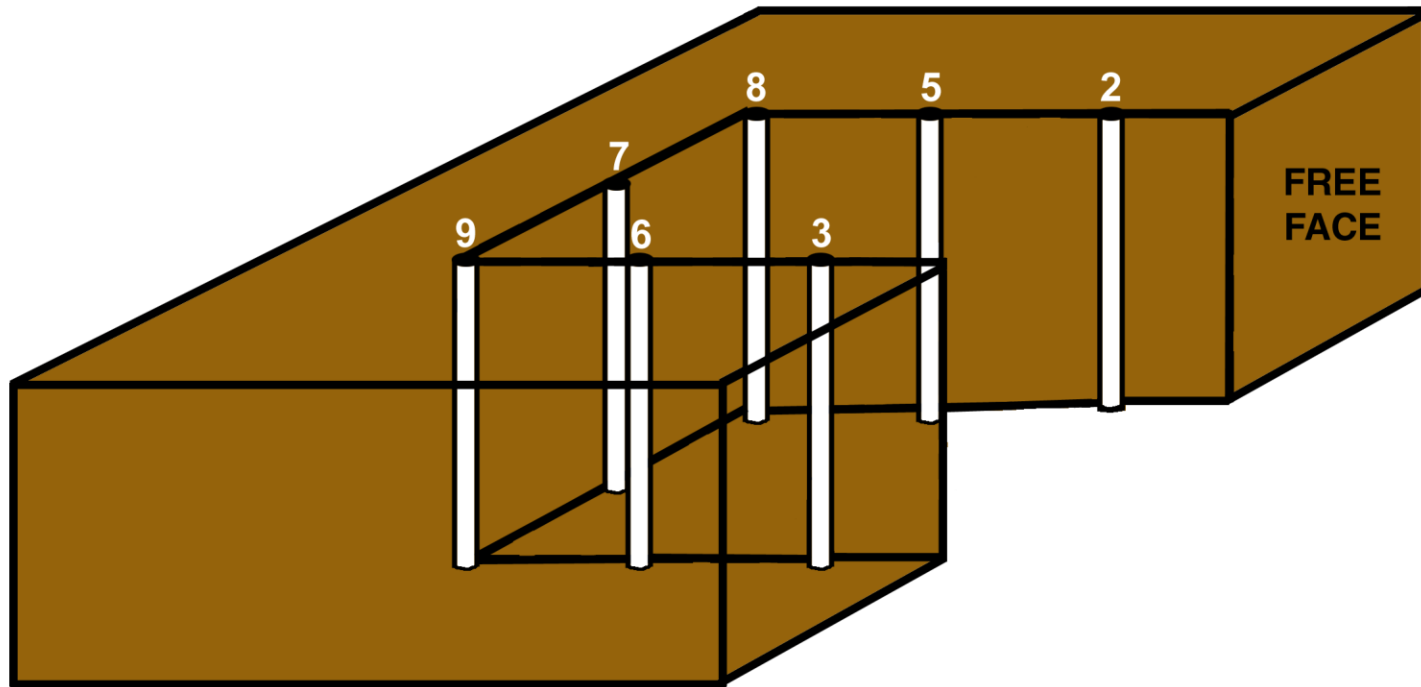
Bench Blast Round - After Delay 2



Bench Blast Round - After Delay 4

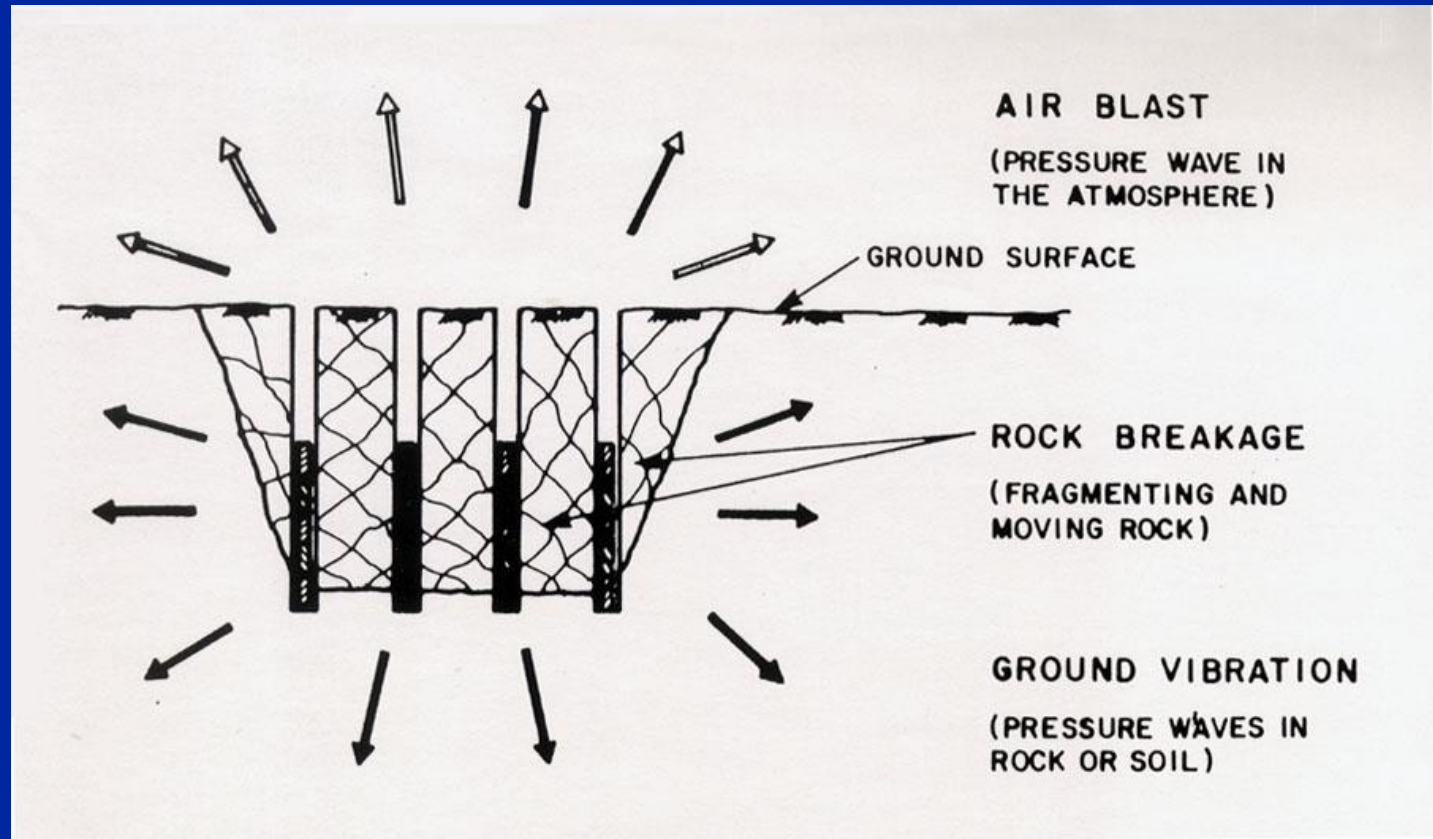


Bench Blast Round - After Blasting Completed



Impacts of Blasting

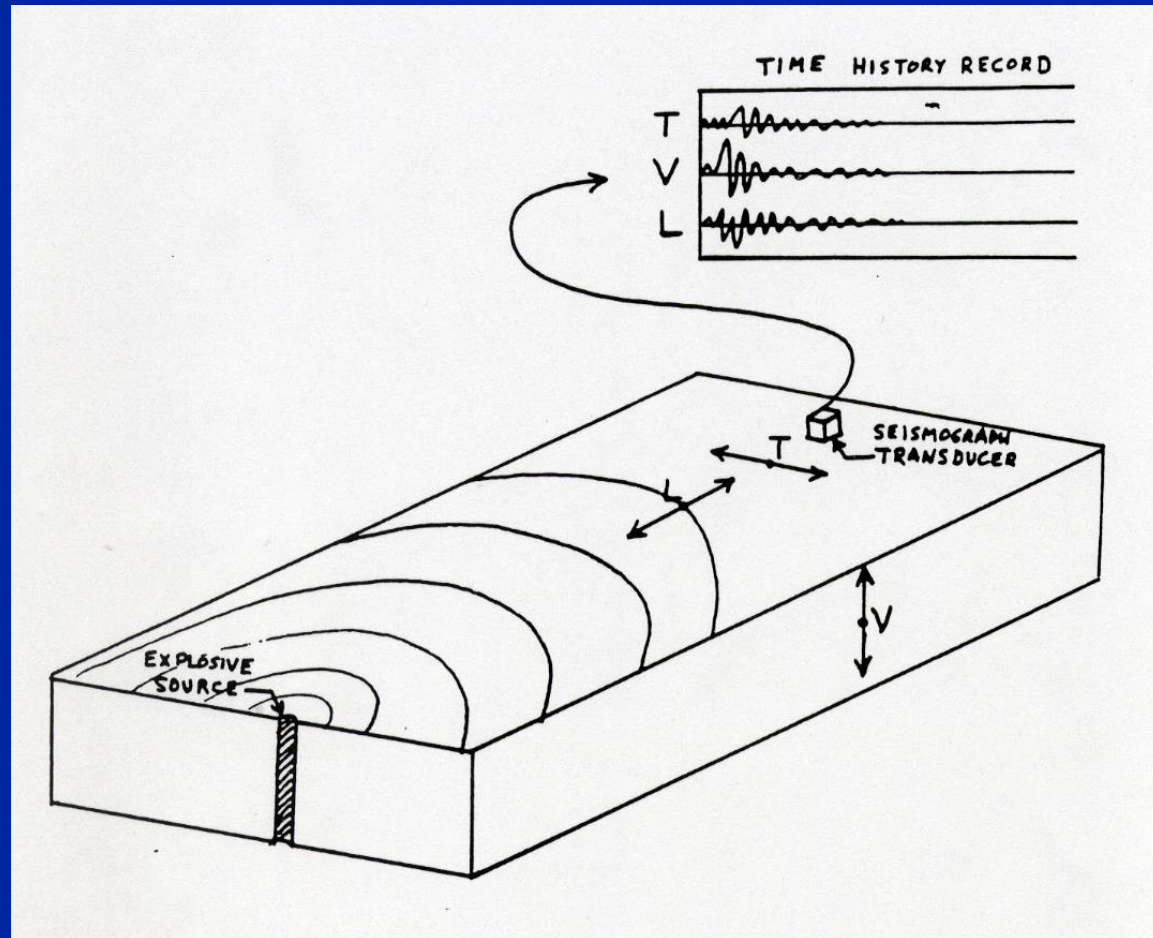
Results of Explosive Energy Release



Undesirable Side Effects of Blasting

- Elastic Ground Vibrations
- Airblast Overpressure
- Permanent Non Elastic Ground Deformations
- Flyrock

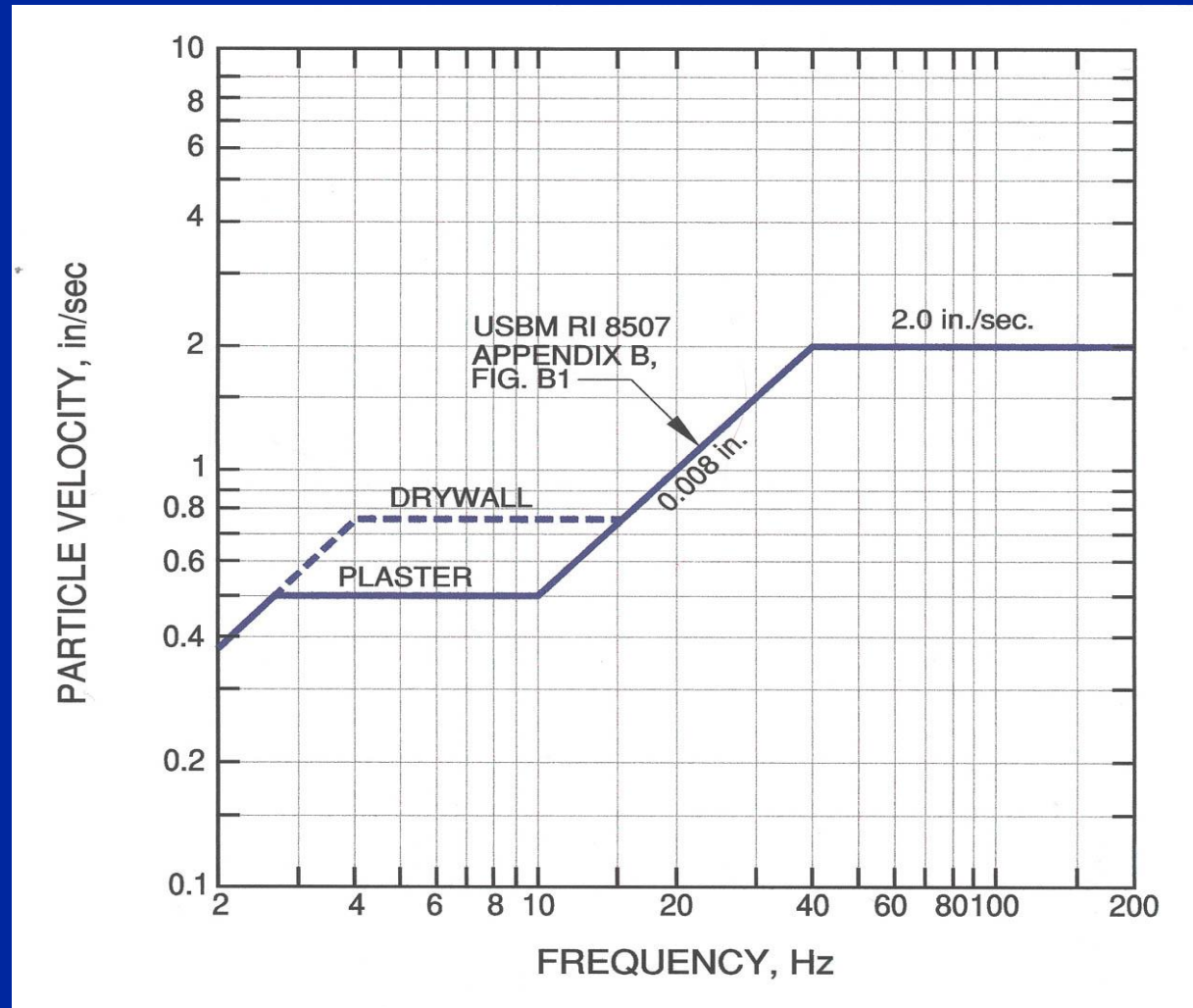
Seismograph Monitoring of Elastic Ground Vibrations



Measurement of Elastic Ground Vibrations

- Peak Particle Velocity, inches per second (in/sec)
- Acceleration, inches per second ² (in/sec²)
- Displacement, inches (in)
- Frequency, cycles per second, or Hertz (Hz)

USBM Safe Vibration Limits for Residential Structures



USBM Safe Limits – What they are and What they are not

Safe Limit to prevent cosmetic damage to residential structures (plaster cracks, NOT structural damage)

Safe limit, Not damage threshold, set at < 5% probability of cosmetic damage. (3 to 5 in/sec to get 50% probability of cosmetic damage)

USBM Safe Limits – What they are and What they are not

Not safe limit for massive engineered structures, underground structures, pipelines, etc, only residential structures. Safe Limit higher for these structures.

Vibration Limits, Underground Structures, Pipes

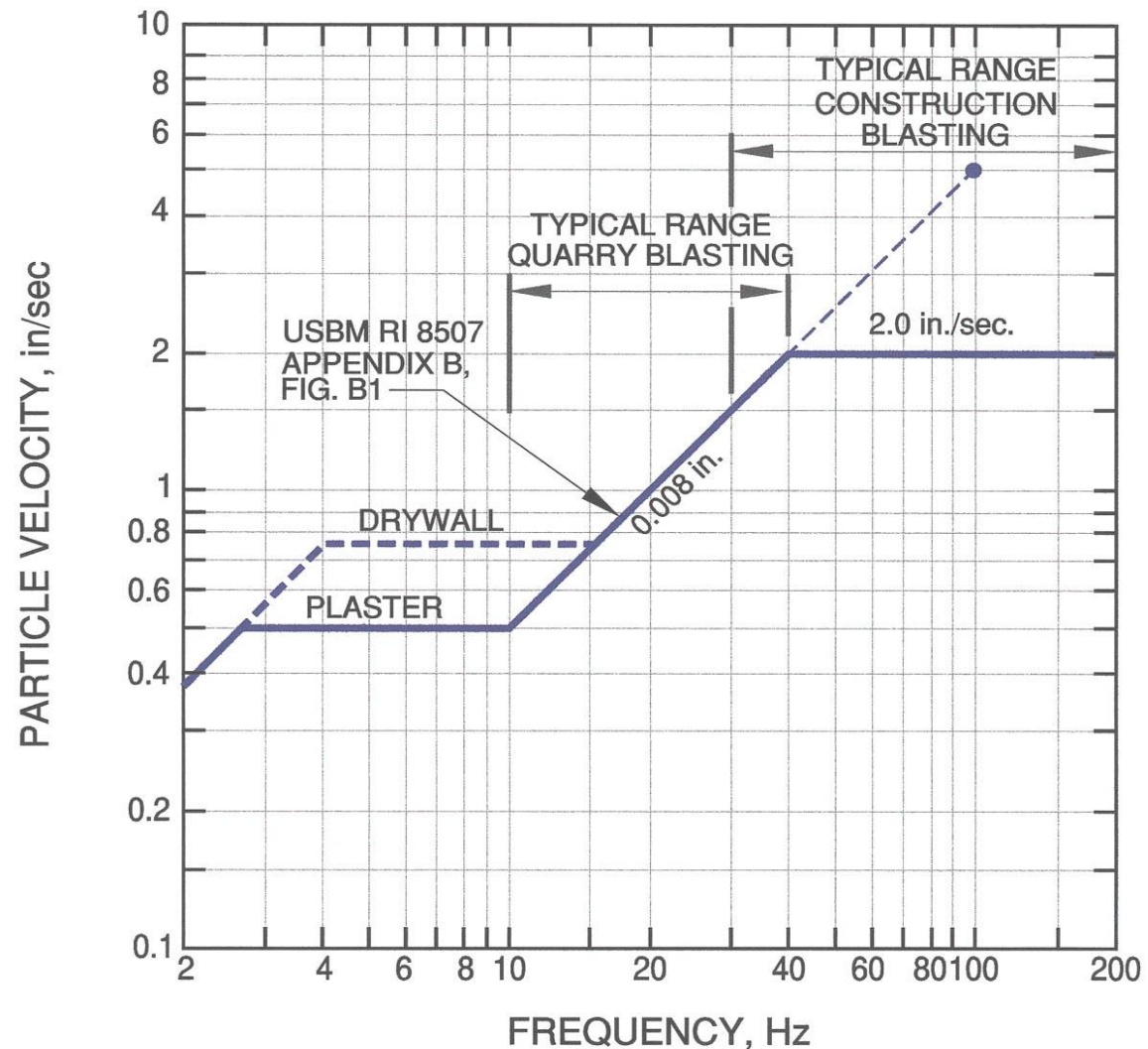
Buried Structures: Bridge Abutments, Retaining Walls, Fdn Walls, Pipelines

- Massive, strong materials**
- Confined By Ground**

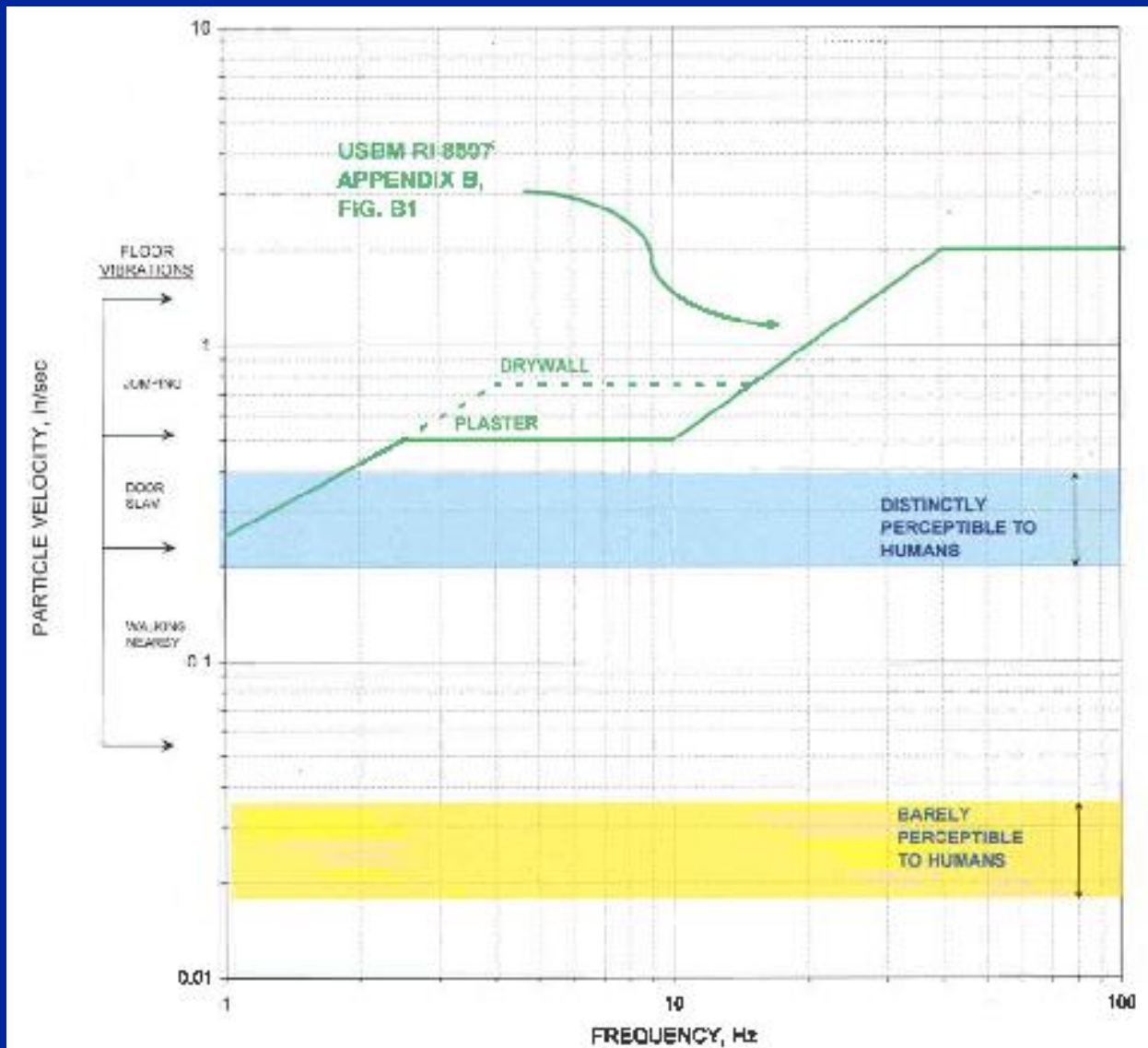
Safe PPV: Reinf concr: 4-8 in/sec

Gas pipelines: 5-10 in/sec

USBM Safe Vibration Limits with Typical Frequency Ranges

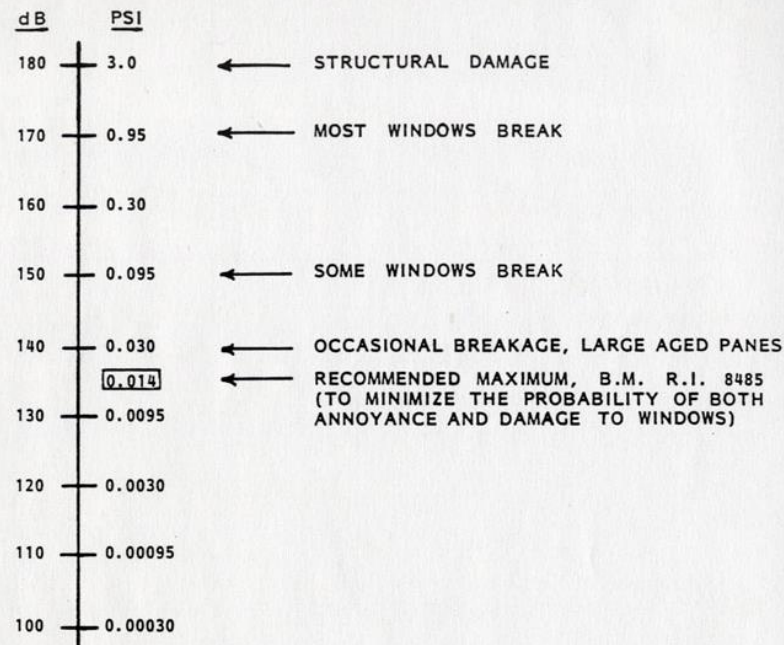


Human Response to Vibrations, and Typical Floor Vibrations



Air Blast Overpressure Damage Criteria

AIR BLAST OVERPRESSURE



$$dB = 20 \log \left(\frac{P}{P_0} \right)$$

WHERE dB = OVERPRESSURE IN DECIBELS (LINEAR PEAK)

LOG = COMMON LOGARITHM

P = OVERPRESSURE IN POUNDS PER SQUARE INCH (PSI)

P₀ = 3 X 10⁻⁹ PSI

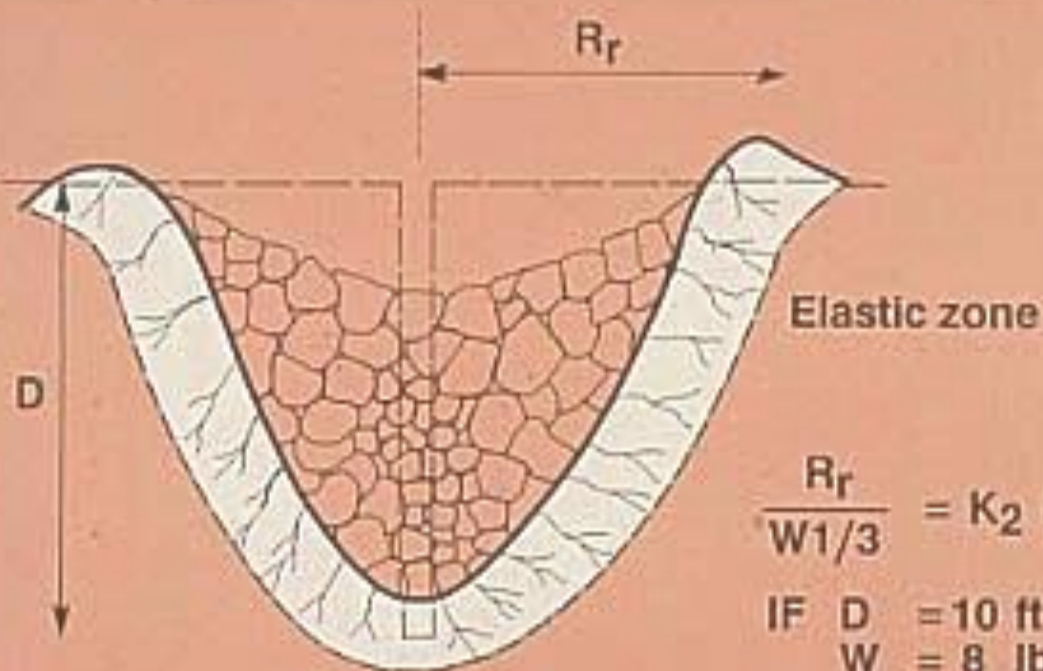
Permanent Non Elastic Ground Deformation

For Close In Blasting

- Below Level Of Adj. Structure**
- Within 0 To About 20 To 40 Ft**

**Permament Ground Deformations
(Ground Heave, Block Movement)
May Be GREATEST THREAT To
Structure Or Utility.**

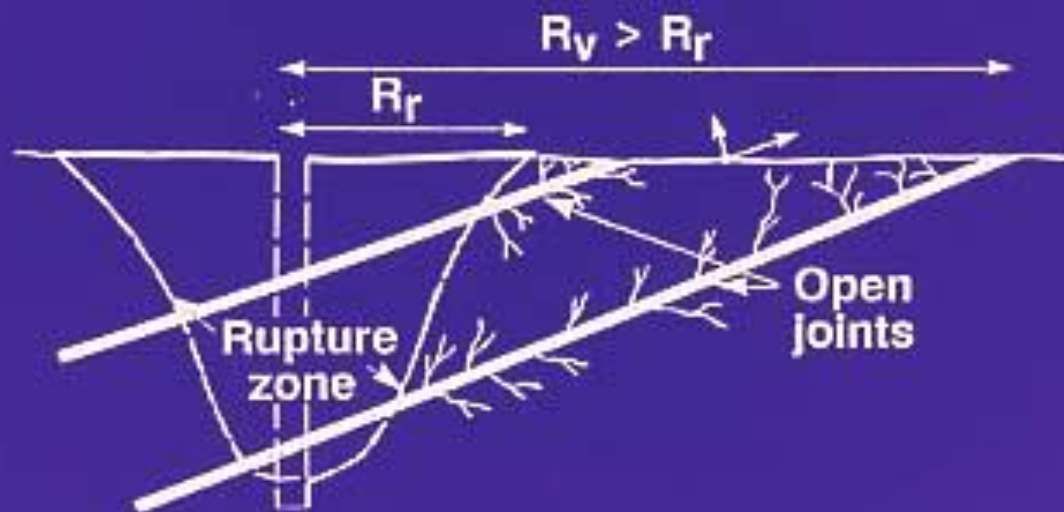
CRATERING RUPTURE ZONE



$$\frac{R_r}{W^{1/3}} = K_2 \left(\frac{D}{W^{1/3}} \right)^{1/4}$$

IF $D = 10$ ft
 $W = 8$ lbs
 $K_2 = 3 \pm$
 $R_r = 9$ ft

DAMAGE AND BLOCK MOVEMENT FROM GAS VENTING



Protective Measures Against Excessive Ground Deformations

- **Provide Good RELIEF**
- **Observe Geology**
- **Watch For/Monitor Ground Heave, Block Movement**
- **Closer Hole Spacing, Smaller Dia. Holes**
- **Good perimeter control blasting to minimize overbreak.**

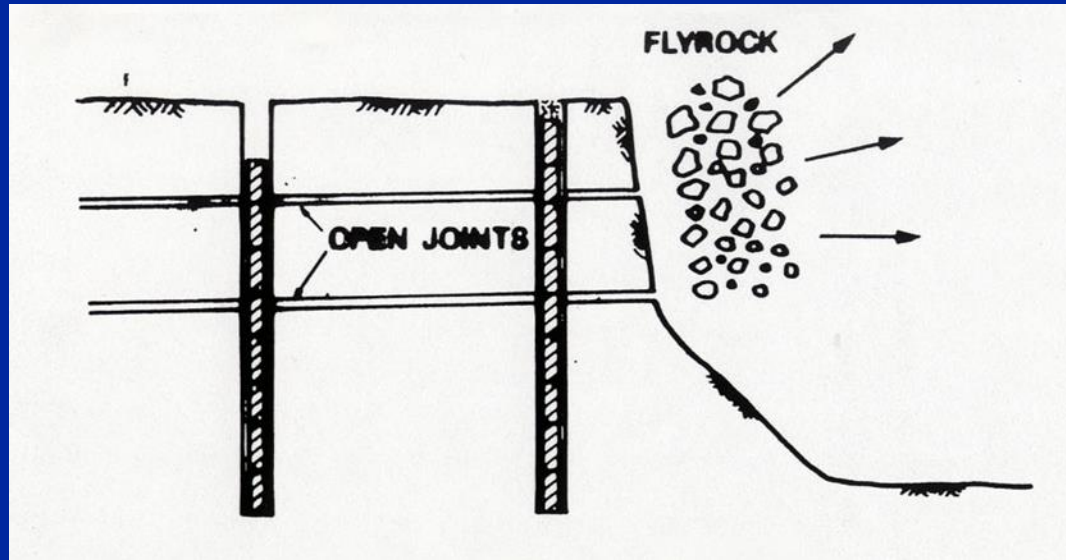
Flyrock - Undesirable throw of rock fragments from a blast round

- Throw of blasted rock beyond the safe blasting area

Why Flyrock Undesirable

1. Causes real damage
2. Injury potential

Some Causes of Flyrock



- Rock discontinuities (open joints, seams, cavities)
- Overloading of holes
- Insufficient stemming
- Inadequate burden
- Improper timing
- Lack of blasting mats

Flyrock

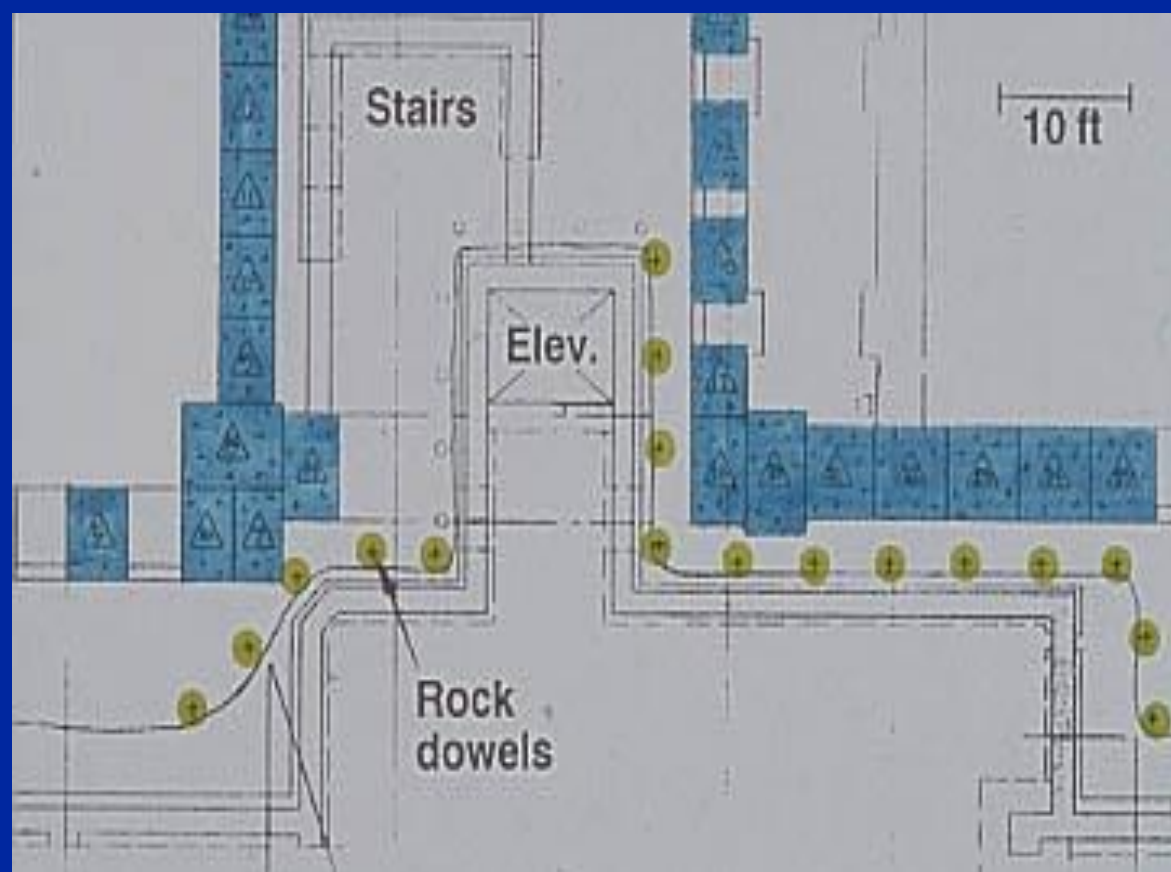
Measures to Prevent Flyrock

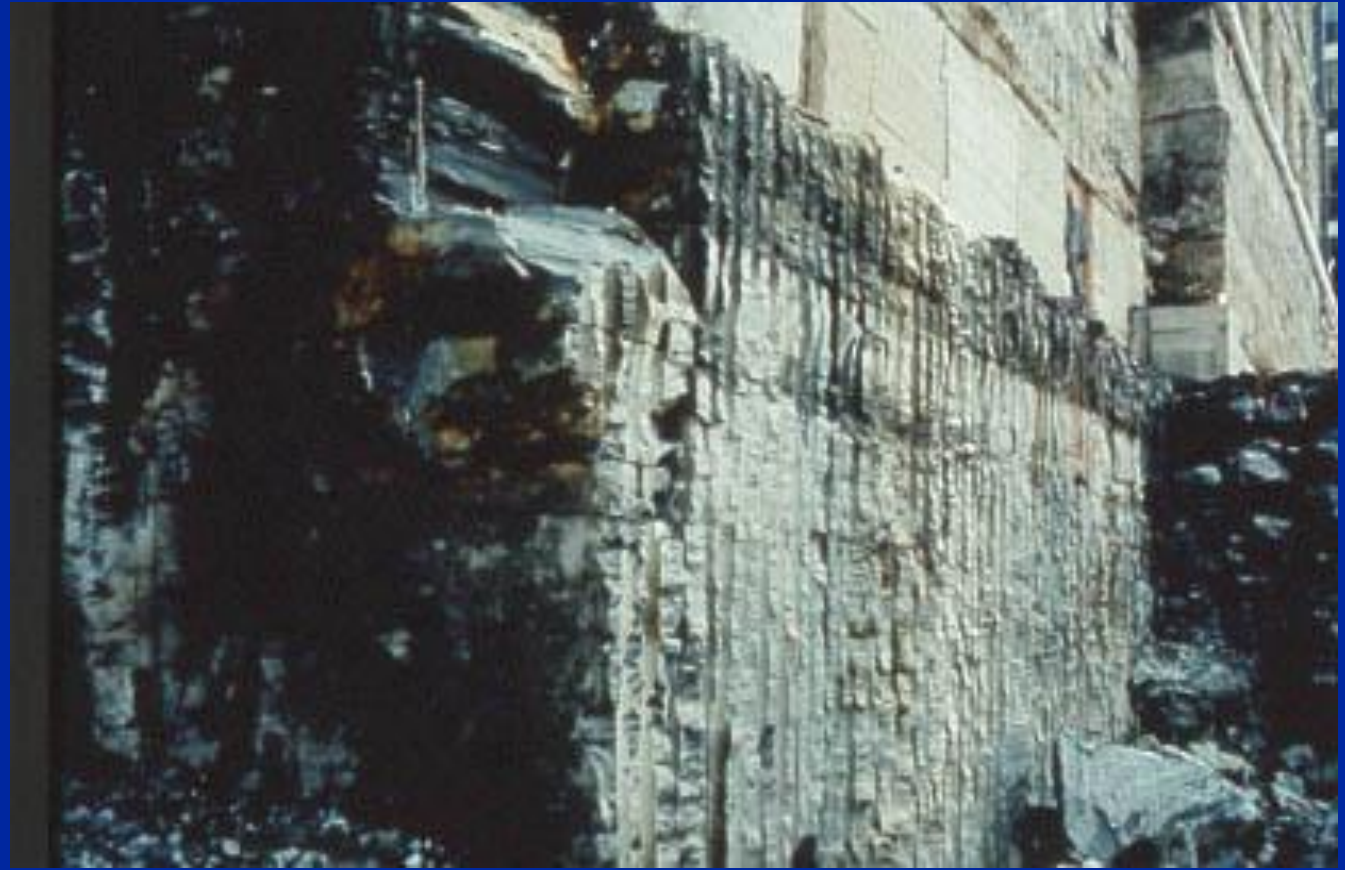
- **Use Blasting Mats**
- **Observe Geology, look for open seams**
- **Videotape blast rounds – watch for little problems, prevent bigger problems**
- **Closer Hole Spacing, Smaller Dia. Holes**
- **Don't use ANFO in built up areas (free pouring, produces more gasses)**

CLOSE IN BLASTING CASE HISTORYS

- **Cornell Underground Library**
- **Maine Statehouse**
- **Charles River Park (Adjacent to Mass General Hospital)**





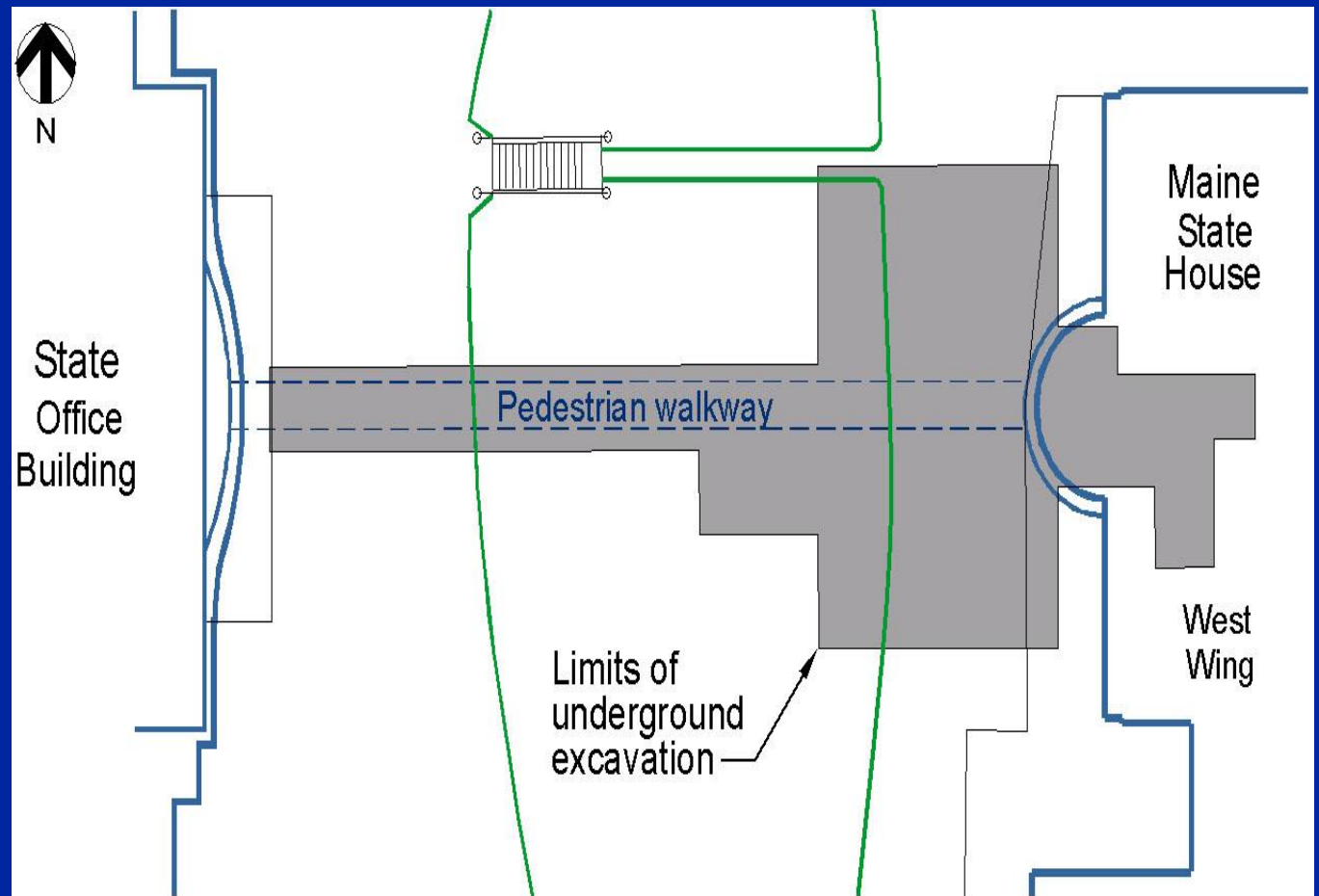






Maine Statehouse Addition Blasting













Charles River Park High Rise Project: Blasting 80 ft from Mass. General Hospital



Up to 35 ft rock cuts, Blasting 80 ft from Hospital with Spinal Surgery on Second Floor, Sensitive Equipment throughout



Protecting Against Claims Resulting from Blasting

Public Relations Program

Key Elements:

- Pre-blast Information Meeting with Neighbors
 - Review Blast Impacts, Mitigations Measures
 - Will Feel vibrations, doesn't mean damage
 - Answer Questions
- Pre-blast condition surveys
 - Opportunity for public relations
 - Point out there are existing cracks
- Periodic Progress Meetings with Neighbors

Minimizing Impacts from Drilling and Blasting

Controlled Blasting Specification

Key Elements:

- Pre-blast condition survey
- Reasonable Blast Vibration Limits
- Pre-Qualification of Blasting Contractor
- Good blasting plan
- Use of blasting mats, Videotaping of Blasts
- Monitoring of Vibrations, Airblast, Crack Gages, Heave

Pre-Blast Condition Survey

- **Document structure condition: Photos and comments, or videotape with comments**
- **Alert home owners to existing cracks**
- **Provide information to alleviate fears and concerns**

Set Reasonable Blast Vibration Limits for Project and Site

- Houses: Use USBM Safe Limits
- Close in Engineered Structures (Massive reinforced concrete Bldg), consider higher levels
- Close in pipelines, consider higher levels
- Set settlement, heave criteria at close in structures, utilities

Pre-Qualification of Blasting Contractor

- **Min 5 yrs of experience with similar type of blasting.**
- **Experience with blasting close to pipelines, structures.**
- **Min \$5,000,000 XCU Liability Insurance.**

Blasting Plan

- Well thought out blast round design
- Use of scaled distance relationships to set conservative initial max. charge wt. per delay
- Develop rock excavation using:
 - Free surface if available
 - Start at furthest point to buildings
- Good Perimeter Control Blasting design

Vibration, Heave, Crack Gage Monitoring

- Vibration Monitoring at nearest structures for every round
- At other critical structures, if required
- Heave monitoring if close in structures, utilities
- Crack gage monitoring on selected existing cracks in structures.
- Complete blast monitoring reports, keep on file with time history tapes.

Summary

- Ground Vibration, Airblast Overpressure generally produce most concern to Engineers and the Public, but almost never produce any real damage. Human perception is issue. Good Public Relations is Solution
- USBM Safe Limits prevent COSMETIC damage to RESIDENTIAL structures. NOT structural damage limit, NOT threshold damage limit.
- Engineered structures, underground structures, pipelines, can and should have higher vibration limits.
- Flyrock is single biggest threat from blasting.

Summary (cont.)

- Displacements important for close-in blasting
 - Elastic displacement < 0.008 in.
 - Non elastic displacement. Can be > 1 in.
 - Block movement
 - Ground heave
- Protect against non-elastic displacement
 - Look for open joints/seams
 - Prevent excessive confinement
 - Adequate powder factor
 - Line drilling/cushion blasting at perimeter

Recommended conditions for Special Permit Decision

- **Independent Blasting Consultant for Town of Brookline- McKown Associates**
 - Review Quals of Blasting Contractor
 - Review Blasting Plan
 - Check seismograph placement, calibration
 - Ongoing review of Blast vibration data.
 - Consult with Brookline Fire Department
- **Preblast Surveys to 300 ft from blasting; except 400 ft around Building 10 (30 ft rock cuts)**

Recommended conditions for Special Permit Decision

- Insurance Coverage: \$5,000,0000.
comprehensive Liability Insurance for damage to structures caused by underground explosion and collapse hazard.
- Blasting Vibration Limits: State (USBM) Safe Limits
- Airblast Overpressure Limits: State (USBM) Safe Limits
- Notification: Not less than 72 hours prior to commencement of any blasting, hand written notifications to all properties entitled to pre blast condition surveys

Recommended conditions for Special Permit Decision

- **Road Closures of adjacent streets kept to a minimum and coordinated with Police, Fire, and Engineering Departments.**
- **Detailed Blast Plan for Review by Town Blasting Consultant**
- **Blast Vibration Monitoring for each blast, minimum 5 locations around blast area**
- **Hours of Drilling and Blasting Limited to 9 AM to 4 PM**
- **Warning Signals to alert residents prior to each blast (Horn or Whistle)**

Recommended conditions for Special Permit Decision

- **Flyrock Protection Measures:**
 - **Blasting Mats to cover all blasts**
 - **Drillers Logs kept, reviewed by blaster**
 - **No ANFO use on site**
 - **Videtape of each blast (See little problems and correct before they become bigger)**

Recommended conditions for Special Permit Decision

- **Noise Reduction Measures**
 - Mufflers on Drills
 - Max Noise Levels at nearest residence
86dBA
 - Measurements periodically with A weighted Sound Level Meter.

Recommended conditions for Special Permit Decision

- **Dust Protection Measures:**
 - **No Rock Crushers on Site**
 - **Dust Collectors on all Drill rigs**
 - **Wetting down blast muck**
 - **Covers on Trucks transporting rock muck**
 - **Dust Level Limits at Property Lines: 150 micrograms per cubic meter of air (PM10 Breathable particulate matter)**
 - **Continuous monitoring at 5 locations.**

Recommended conditions for Special Permit Decision

- **Stability of Rock Cut Slopes**
 - **At Parking Garage, other permanent rock cuts 10 ft or greater, utilize perimeter control blasting procedures (Presplitting, Trim Blasting, Line drilling) to provide safe and stable final slope.**

QUESTIONS?